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Green Space Visits among Adolescents: Frequency and Predictors in the PIAMA Birth Cohort Study

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Background: Green space may influence health through several pathways, for example, increased physical activity, enhanced social cohesion, reduced stress, and improved air quality. For green space to increase physical activity and social cohesion, spending time in green spaces is likely to be important.

Objectives: We examined whether adolescents visit green spaces and for what purposes. Furthermore, we assessed the predictors of green space visits.

Methods: In this cross-sectional study, data for 1911 participants of the Dutch PIAMA (Prevention and Incidence of Asthma and Mite Allergy) birth cohort were analyzed. At age 17, adolescents reported how often they visited green spaces for physical activities, social activities, relaxation, and to experience nature and quietness. We assessed the predictors of green space visits altogether and for different purposes by log-binomial regression.

Results: Fifty-three percent of the adolescents visited green spaces at least once a week in summer, mostly for physical and social activities. Adolescents reporting that a green environment was (very) important to them visited green spaces most frequently {adjusted prevalence ratio (PR) [95% confidence interval (CI)] very vs. not important: 6.84 (5.10, 9.17) for physical activities and 4.76 (3.72, 6.09) for social activities}. Boys and adolescents with highly educated fathers visited green spaces more often for physical and social activities. Adolescents who own a dog visited green spaces more often to experience nature and quietness. Green space visits were not associated with the objectively measured quantity of residential green space, i.e., the average normalized difference vegetation index (NDVI) and percentages of urban, agricultural, and natural green space in circular buffers around the adolescents' homes.

Conclusions: Subjective variables are stronger predictors of green space visits in adolescents than the objectively measured quantity of residential green space. https://doi.org/10.1289/EHP2429

Introduction

Exposure to green space may be associated with beneficial health effects, including improved pregnancy outcomes, reduced cardiovascular morbidity and mortality, and improved mental health. However, only few studies examined the effects of green space on the health of adolescents (Banay et al. 2017; Dzhambov et al. 2014; Gascon et al. 2015; James et al. 2015; Nieuwenhuijsen et al. 2017).

Green space may influence health through several pathways. For example, green space may influence health by providing opportunities for physical activity, enhancing social cohesion, reducing stress, decreasing noise levels, and improving air quality (Hartig et al. 2014; Markevych et al. 2017; Nieuwenhuijsen et al. 2017). However, very few studies have examined the contribution of the different pathways between green space and morbidity (Nieuwenhuijsen et al. 2017). Reduced stress, decreased noise levels, and improved air quality can beneficially affect health without individuals consciously engaging with green space (Hartig et al. 2014). In contrast, for green space to increase physical activity and social interaction, actual green space visits are likely to be important. It is therefore important to examine whether people actually spend time in green spaces and for what purposes green spaces are visited to get more insights into the contribution of different pathways.

Generally, objectively measured surrounding greenness and/or access to green space are used in epidemiological studies, assessed by land use maps or remote sensing indices such as the normalized difference vegetation index (NDVI) (Dadvand et al. 2012; Huynh et al. 2013; Markevych et al. 2014). A limitation of assessing exposure merely through the presence of green space is the lack of data on the actual green space visits by the study participants.

To our knowledge, only few studies have examined green space visits by adolescents. A study conducted in the United States found that adolescents used parks more often for physical activity when there was higher perceived park availability, park quality, and park use by friends (Ries et al. 2009). A study in California showed that increasing age was associated with a decreased likelihood of being physically active in parks and that females were less often physically active in parks than males (Babey et al. 2015). However, these studies did not focus on visits to green spaces other than parks that may also affect the health of adolescents. Additionally, the studies mainly focused on physical activity and not on any of the other proposed pathways.

In the present study, we aim to examine whether adolescents visit green spaces and for what purposes. We also aim to identify the predictors of green space visits.

Methods

Study Design and Population

This study used data from the Dutch Prevention and Incidence of Asthma and Mite Allergy (PIAMA) birth cohort. Detailed descriptions of the PIAMA study have been published previously (Brunekreef et al. 2002; Wijga et al. 2014). In brief, pregnant

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women were recruited from the general population in three different parts of Netherlands during their second trimester of pregnancy. Their children were born in 1996–1997 ($n = 3{,}963$ at baseline) and have been followed from birth up to the age of 17 y. Questionnaires were sent to the participating parents during pregnancy, 3 mo after the child was born, when the child was 1 y old, and yearly thereafter until the child was 8. When the children were 11, 14, and 17 y old, both parents and children were asked to complete a questionnaire. The study protocol has been approved by the medical ethical committees of the participating institutes, and written informed consent was obtained from the parents of all participants.

The present cross-sectional study used data from the questionnaires completed by parents and adolescents at the age of 17 y. At this age, 3,109 families (78.5% of 3,963) were still participating in the study and received questionnaires: one questionnaire for the adolescents and one questionnaire for the parents. In total, 2,096 adolescents (67.4% of 3,109; 52.9% of 3,963) and 1,875 parents completed their questionnaire. Most of the information used in the present study was obtained from the questionnaire for the adolescents. However, information on some of the potential predictors of green space visits, such as dog ownership and parental level of education, was obtained from the parental questionnaire. Adolescents with complete information on green space visits and potential predictors thereof were included in this study. This resulted in a study population of 1,911 adolescents.

Definition of Green Space Visits as the Outcome Variable

The frequency of green space visits was assessed with the following question: "How often do you intentionally go to a green environment (not your own garden) for the following activities: physical activities (e.g., walking, cycling, doing sports), social activities (e.g., meeting friends, having a picnic), relaxation (e.g., reading, resting, watching people, sunbathing), and to experience nature and quietness?" Answering options were "never," "less than once a month," "1–3 times a month," "once a week," and "more than once a week." We assumed that green spaces may be beneficial to health when they are visited regularly. Therefore, five binary outcome variables were created: Visiting green space at least once a week for *a*) physical activities (yes/no); *b*) social activities (yes/no); *c*) relaxation (yes/no); *d*) experiencing nature and quietness (yes/no); and *e*) any of the types of activity mentioned before (yes/no). Participants reported how often they visited green spaces in summer and in winter. Since only a small percentage of adolescents visited green spaces in winter (Figure 1), we only assessed predictors of green space visits in summer.

Definition of Potential Predictors

Sociodemographic characteristics. We included the child's sex and several indicators of socioeconomic status (SES): maternal and paternal level of education (obtained from the 1-y questionnaire), the participant's level of education (obtained from the 17-y questionnaire), and area-level SES [based on status scores of four-digit postal code areas of 2014 from Statistics Netherlands (Knol 2012)]. Status scores include the average income, the percentage of residents with a low income, the percentage of low-educated residents, and the percentage unemployed subjects in a postal code area. A higher status score indicates a higher neighborhood SES (Knol 2012). Maternal and paternal education were divided into three categories: primary school only or lower secondary or lower vocational education (low), intermediate vocational education or intermediate or higher secondary education (intermediate), and higher vocational education or university (high). The educational level of the adolescents was divided into two categories: lower secondary or lower vocational education, intermediate secondary, or intermediate vocational education (low/intermediate), higher secondary education or higher vocational education or university (high).

Urbanization. Data on address density as an indicator of the degree of urbanization per four-digit postal code for 2011 were obtained from Statistics Netherlands (Centraal Bureau voor de Statistiek 2016). Statistics Netherlands divides address density into five categories: ≥2,500 addresses per km^2; 1,500 to 2,500 addresses per km^2; 1,000 to 1,500 addresses per km^2; 500 to 1,000 addresses per km^2; and <500 addresses per km^2.

Dog ownership. Parents of the adolescents answered the following questions: "Do you have a dog at home?" and if yes, "How many hours per week does your child walk the dog outside?" Responses to the questions were used to create a variable with the following categories: does not own a dog, owns a dog and adolescent walks the dog 1 h or less per week, and owns a dog and adolescent walks the dog more than 1 h per week. Since information on dog ownership was missing for 271 adolescents (14.2%), we created a fourth category, "no information available

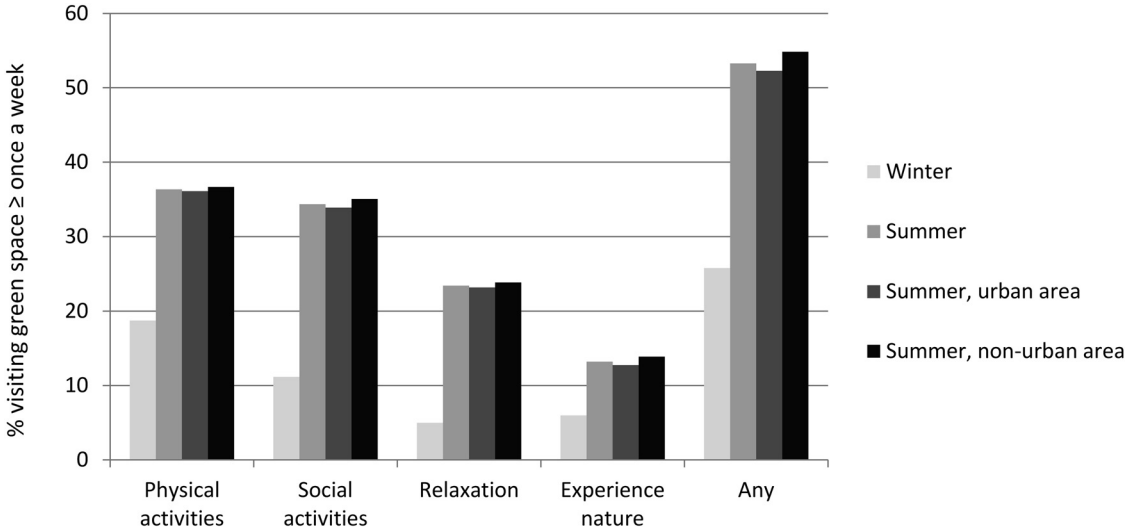

Figure 1. Percentage of adolescents visiting green spaces at least once a week according to type of activity, winter or summer season, and level of urbanization for visits during the summer. Urban area: ≥1,000 addresses per km^2; nonurban area: <1,000 addresses per km^2.

about dog ownership," to avoid that these adolescents would be excluded from the analyses.

Perceived importance of a green environment. For each type of activity (i.e., physical activities, social activities, relaxation, and to experience nature and quietness), adolescents reported whether a green environment was "not important," "somewhat important," "important," or "very important" to them. Our questionnaire did not contain a question about the importance of a green environment for green space visits in general, i.e., for any type of activity. We therefore combined the responses to the four separate activities to create a variable with three categories for the outcome "visiting green space at least once a week for any type of activity": not important, somewhat important, and important.

Perceived neighborhood greenness. Adolescents were asked to classify their neighborhood as very green, green, moderately green, little green, or not green. Since only a small group of adolescents reported that their neighborhood was not green, we combined the latter two categories into one: little to no green.

Quantity of residential green space. Different indicators were used to objectively assess the quantity of green space within certain distances of the adolescent's home. To assess surrounding greenness levels, we used the NDVI, derived from Landsat 5 Thematic Mapper (United States Geological Service, https://earthexplorer.usgs.gov/) data at 30 m × 30 m resolution. NDVI values range from −1 to 1, with higher values indicating more greenness (Weier and Herring 2000). Negative values correspond to water and were set to zero so that the effects of water surfaces do not negate the presence of green space (Markevych et al. 2014). Several options to handle negative NDVI values are available (Markevych et al. 2017). We could have artificially reduced the average NDVI by recoding negative values to zero, as compared to removing negative NDVI values. However, the average percentage of water in a buffer of 3,000 m was only 6.29 in our study population, so we assume that this has not substantially affected our estimates of greenness exposure. We generated a map of Netherlands by combining cloud-free images of the summer of 2010. For each adolescent, surrounding greenness was assessed by calculating the average NDVI in buffers of 100 m, 300 m, 500 m, 1,000 m, and 3,000 m around his/her home. The buffers of 100 m, 300 m, and 500 m represent the quantity of green space near the adolescent's home, whereas the buffers of 1,000 m and 3,000 m represent the quantity of green space in a larger area around the adolescent's home. We hypothesize that green spaces close to home may have a different effect on the frequency of green space visits than green spaces in a larger area around the home.

We hypothesized that different types of green space may have different effects on green space visits. Top10NL (https://www.kadaster.nl/brt) is a detailed land-use map of Netherlands (Kadaster 2014). In contrast to the NDVI, street greenery and private green property (such as gardens) are not included in the Top10NL. We used Top10NL of 2015 to assess the percentages of urban green, natural green, and agricultural green in buffers of 100 m, 300 m, 500 m, 1,000 m, and 3,000 m around the residential addresses. To distinguish between different types of green space, we defined all green spaces within a "population cluster" as "urban green space." A population cluster is defined as a locality with at least 25 predominantly residential buildings (Vliegen et al. 2006). The remaining green spaces were classified as "agricultural green space" (arable land, fruit or tree nurseries, orchards, or grassland) and "natural green space" (forests or heather). A total of 57% of the adolescents had no natural green space in the 300-m buffer around their homes (Table 1). Therefore, a binary variable was created: natural green space in a buffer of 300 m: yes/no. Both the average NDVI and the percentages of urban, agricultural, and natural green space in different buffer sizes were highly correlated (Table S1). We therefore decided to include the buffers of 300 m, 1,000 m, and 3,000 m only in the present analyses, and did not perform analyses with the indicators of the quantity of green space in buffers of 100 m and 500 m.

Table 1. Characteristics of the study population and potential predictors of green space visits ($n = 1{,}911$).

Characteristic	n (%), mean ± SD, or median (25th–75th percentiles)
Sex	
Girl	974 (51.0)
Boy	937 (49.0)
Age in years	17.8 ± (0.3)
Maternal level of education	
Low	339 (17.7)
Intermediate	780 (40.8)
High	792 (41.4)
Paternal level of education	
Low	400 (20.9)
Intermediate	638 (33.4)
High	873 (45.7)
Educational level of adolescent	
Low/intermediate	1,015 (53.1)
High	896 (46.9)
Neighborhood SES[a]	0.5 (−0.1 to 1.3)
Urbanization	
≥2500 addresses per km^2	153 (8.0)
1,500–2,500 addresses per km^2	638 (33.4)
1,000–1,500 addresses per km^2	378 (19.8)
500–1,000 addresses per km^2	443 (23.2)
<500 addresses per km^2	299 (15.7)
Owning a dog	
Does not own a dog	1,198 (62.7)
Owns a dog, and walks the dog ≤1 h per week	267 (14.0)
Owns a dog, and walks the dog >1 h per week	175 (9.2)
No information available about dog ownership	271 (14.2)
Importance of a green environment	
Not important	589 (30.8)
Somewhat important	757 (39.6)
Important	565 (29.6)
Perceived neighborhood greenness	
Very green	297 (15.5)
Green	871 (45.6)
Moderately green	643 (33.7)
Little to no green	100 (5.2)
Distance from home to the nearest park	
≤300 m	645 (33.8)
300–1,000 m	845 (44.2)
>1,000 m	421 (22.0)
Average NDVI in 300-m buffer[b]	0.55 (0.48–0.61)
Average NDVI in 1,000-m buffer[b]	0.58 (0.51–0.65)
Average NDVI in 3,000-m buffer[b]	0.62 (0.56–0.68)
Percentage urban green in 300-m buffer	9.7 (4.4–15.6)
Buffers that have no urban green	112 (5.9)
Percentage urban green in 1,000-m buffer	9.2 (5.1–13.9)
Buffers that have no urban green	54 (2.8)
Percentage urban green in 3,000-m buffer	6.0 (2.9–9.7)
Buffers that have no urban green	7 (0.4)
Percentage agricultural green in 300-m buffer	1.1 (0.0–16.3)
Buffers that have no agricultural green	829 (43.4)
Percentage agricultural green in 1,000-m buffer	18.8 (4.9–39.8)
Buffers that have no agricultural green	173 (9.1)
Percentage agricultural green in 3,000-m buffer	39.9 (23.7–55.4)
Buffers that have no agricultural green	0.0 (0.0)
Percentage natural green in 300-m buffer	0.0 (0.0–1.3)
Buffers that have no natural green	1091 (57.1)
Percentage natural green in 1,000-m buffer	1.8 (0.3–5.7)
Buffers that have no natural green	244 (12.8)
Percentage natural green in 3,000-m buffer	4.1 (2.1–10.0)
Buffers that have no natural green	0.0 (0.0)

Note: NDVI = normalized difference vegetation index; SD, standard deviation; SES, socioeconomic status.
[a]A higher score indicates a higher SES.
[b]NDVI values range from 0 to 1, with higher values indicating more greenness.

Bestand Bodemgebruik is another land-use map of Netherlands (Centraal Bureau voor de Statistiek 2008). It is less detailed than Top10NL (it contains fewer land-use categories), but in contrast to Top10NL, it contains a separate category for parks defined as public green spaces that are used for relaxation. With a detailed map covering all roads and paths of Netherlands, we estimated the distance along roads (i.e., network distance) in meters from the adolescents' homes to the nearest park. A categorical variable was created: has a park within 300 m of the residential address, has a park within 300 m to 1,000 m of the residential address, and has no park within 1000 m of the residential address.

We included the following objectively measured indicators of the quantity of residential green space in the analyses: *a*) the average NDVI in buffers of 300 m, 1,000 m, and 3,000 m around the adolescent's home; *b*) the percentage of urban, agricultural, and natural green space in buffers of 300 m, 1,000 m, and 3,000 m around the adolescent's home; and *c*) the distance from the home address to the nearest park. These indicators of the quantity of residential green space were determined in ArcGIS (version 10.2.2; Esri).

Statistical Analyses

First, we investigated the shape of the unadjusted relationships between continuous predictors and visiting green space at least once a week (yes/no) by generalized additive models with integrated smoothness estimation and a log link [GAM function of R (version 2.8.0; R Development Core Team]. Since most of the associations were found to be linear or almost linear, the continuous predictors were not transformed. We used log-binomial regression models to calculate prevalence ratios (PRs) and 95% confidence intervals (95% CIs) (Spiegelman and Hertzmark 2005). We performed analyses of the unadjusted associations between each of the potential predictors and the five outcomes (visiting green space at least once a week for any type of activity, for physical activities, for social activities, for relaxation, and for experiencing nature and quietness). Predictors that were associated with at least one outcome with a p-value of ≤ 0.10 were selected for multivariable modeling with backward variable selection. Simultaneous inclusion of the objectively measured indicators of the quantity of green space in buffers of 300 m, 1,000 m, and 3,000 m in the same model resulted in multicollinearity problems (variance inflation factor >4.5). We therefore decided to include only buffers of 300 m and 3,000 m in multivariable modeling. The Akaike information criterion was used to determine for each of the five outcomes the model that best fit the data, i.e., five outcome-specific models were made (Burnham and Anderson 2002). In the end, we included all predictors that were selected into at least one of the five outcome-specific models in our final model to facilitate the comparison of models between outcomes.

Additionally, stratified analyses by level of urbanization were performed. The level of urbanization was divided into two categories: urban ($\geq$1,000 addresses per km^2) and nonurban (<1,000 addresses per km^2).

Several sensitivity analyses were performed. We repeated the analysis of the predictors of green space visits in summer with the frequency of green space visits in five categories (never, less than once a month, one to three times a month, once a week, more than once a week) by polytomous logistic regression with "never" as the reference category. We also performed sensitivity analyses without the predictor "perceived importance of a green environment" to examine whether other predictors were associated with green space visits in summer when this predictor was omitted. Moreover, we assessed whether the predictors of green space visits in winter differed from the predictors of green space visits in summer. The percentage of adolescents that visited a green space at least once a week in winter for relaxation or to experience nature and quietness was too low to perform the analyses. Therefore, the sensitivity analyses were limited to the frequency of green space visits in winter for physical activities, social activities, and any type of activity. Since log-binomial regression models failed to converge, we assessed the associations between the frequency of green space visits in winter and potential predictors with Poisson regression (Spiegelman and Hertzmark 2005).

The statistical analyses, except the generalized additive models with integrated smoothness estimation, were performed with SAS (version 9.4; SAS Institute Inc.).

Results

Population Characteristics and Frequencies of Green Space Visits

Characteristics of the study population are presented in Table 1. In total, 41% of mothers and 46% of fathers were highly educated, 61% of the adolescents classified their neighborhood as (very) green, and 78% of the adolescents had a park within 1,000 m of their home. The median average NDVI in buffers of 300 m, 1,000 m, and 3,000 m increased with increasing levels of "perceived neighborhood greenness," whereas no such trend was observed for the median percentage of urban green space (Figure S1).

Adolescents reported visiting green spaces mostly for physical activities and social activities and less often for relaxation and to experience nature and quietness (Figure 1). A total of 53% of adolescents visited a green space at least once a week for any type of activity in summer, whereas this percentage was 26 in winter. Participants living in urban areas and participants living in nonurban areas hardly differed in how often they visited green spaces in summer (Figure 1).

Predictors of Green Space Visits

Table S2 displays the unadjusted associations between visiting green spaces at least once a week for different activities and potential predictors of green space visits. The perceived importance of a green environment is the only predictor that was strongly and consistently associated with all five outcomes. Different predictors were associated with the frequency of green space visits for different purposes. For example, adolescents who owned a dog were more likely to visit green spaces at least once a week for physical activities, relaxation, and to experience nature and quietness, while boys visited green spaces more often for physical activities than girls.

Table 2 shows the results from the multivariable log-binomial regression analyses. The perceived importance of a green environment remained the strongest predictor of green space visits in multivariable analyses. Adolescents who reported that a green environment was (very) important to them visited green spaces more often than adolescents for whom a green environment was not important [PR (95% CI): 6.84 (5.10, 9.17) for physical activities and 4.76 (3.72, 6.09) for social activities]. Boys visited green spaces more often for physical and social activities than girls [PR (95% CI) 1.12 (1.01, 1.24); PR (95% CI) 1.15 (1.02, 1.28), respectively] and adolescents who owned a dog were 1.5–1.7 times more likely to visit green spaces at least once a week to experience nature and quietness. Adolescents with a high level of education visited green spaces less often for social activities [PR 0.85 (95% CI: 0.75, 0.96)] and relaxation [PR 0.84 (95% CI: 0.71, 0.99)] than adolescents with a low to intermediate level of education. Participants with highly educated fathers were more likely to visit green spaces at least once a week for physical and social activities and any type of activity compared to adolescents with fathers who were less

Table 2. Predictors associated with visiting green spaces at least once a week (yes/no) from multivariable regression analysis.

Predictor	Physical activities PR (95% CI)	Social activities PR (95% CI)	Relaxation PR (95% CI)	Experiencing nature and quietness PR (95% CI)	Any type of activity PR (95% CI)
Sex					
Girl	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Boy	1.12 (1.01, 1.24)	1.15 (1.02, 1.28)	0.87 (0.74, 1.02)	0.86 (0.70, 1.07)	1.06 (0.99, 1.15)
Paternal level of education					
Low	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Intermediate	1.09 (0.91, 1.29)	1.09 (0.92, 1.29)	1.00 (0.82, 1.23)	1.08 (0.80, 1.45)	1.03 (0.92, 1.16)
High	1.25 (1.06, 1.48)	1.22 (1.03, 1.44)	0.92 (0.75, 1.14)	1.01 (0.75, 1.36)	1.13 (1.01, 1.26)
Educational level of adolescent					
Low/intermediate	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
High	1.02 (0.91, 1.14)	0.85 (0.75, 0.96)	0.84 (0.71, 0.99)	0.82 (0.65, 1.03)	0.95 (0.88, 1.04)
Owning a dog					
Does not own a dog	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Owns a dog, and walks the dog ≤1 hour per week	1.01 (0.86, 1.19)	1.05 (0.90, 1.23)	1.15 (0.92, 1.43)	1.47 (1.10, 1.97)	1.01 (0.90, 1.14)
Owns a dog, and walks the dog >1 hour per week	1.07 (0.93, 1.24)	1.03 (0.85, 1.25)	1.16 (0.91, 1.47)	1.67 (1.23, 2.25)	1.05 (0.92, 1.20)
No information available about dog ownership	0.95 (0.81, 1.10)	1.17 (1.01, 1.34)	1.15 (0.93, 1.42)	1.29 (0.96, 1.73)	1.13 (1.02, 1.25)
Importance of a green environment					
Not important	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Somewhat important	2.53 (1.85, 3.45)	2.04 (1.59, 2.61)	1.85 (1.35, 2.52)	3.54 (1.93, 6.50)	1.82 (1.60, 2.08)
Important	4.55 (3.41, 6.09)	3.81 (3.03, 4.80)	3.48 (2.60, 4.65)	9.62 (5.48, 16.88)	2.16 (1.89, 2.46)
Very important	6.84 (5.10, 9.17)	4.76 (3.72, 6.09)	4.87 (3.53, 6.71)	18.76 (10.69, 32.92)	N/A

Note: Results are derived from log-binomial regression analysis. The prevalence ratios are adjusted for all variables presented in this table. Predictors that are included in at least one of the five outcome-specific models that best fit the data are presented. CI, confidence interval; PR, prevalence ratio.

educated [PR 1.25 (95% CI: 1.06, 1.48); PR 1.22 (95% CI: 1.03, 1.44); PR 1.13 (95% CI: 1.01, 1.26), respectively].

Maternal level of education, area-level SES, and the objectively measured quantity of green space (i.e., the average NDVI and percentages of urban, agricultural, and natural green space in buffers of 300 m and 3,000 m around the participants' homes and the distance to the nearest park) were not significantly associated with green space visits in multivariable analyses (data not shown). We could not add all objectively measured indicators of the quantity of green space at the same time to the models in Table 2 because of multicollinearity problems. The NDVI is the most frequently used indicator to assess exposure to greenness in epidemiological studies. We have therefore decided to only add the average NDVI in buffers of 300 m and 3,000 m at the same time to the models that are displayed in Table 2. The association between the average NDVI and green space visits remained nonsignificant (Table S3).

When we stratified by level of urbanization, we found that the associations between adolescents living in urban areas and adolescents living in nonurban areas were generally very similar (Figure 2). However, adolescents with highly educated fathers only visited green spaces more often for physical and social activities and any type of activity when they lived in an urban area. We found no associations between paternal level of education and green space visits for social activities and any type of activity in adolescents who lived in nonurban areas.

The perceived importance of a green environment was also the strongest predictor of green space visits when the frequency of green space visits was divided into five categories (Tables S4–S8). The results of these sensitivity analyses were generally similar to those of the main analyses except that adolescents with a higher level of education visited green spaces more often for any type of activity than adolescents with a low/intermediate level of education [odds ratio (OR) 1–3 times a month vs. never: 2.57 (95% CI: 1.66, 3.98); OR once a week vs. never: 2.21 (95% CI: 1.42, 3.44); OR more than once a week vs. never: 1.60 (95% CI: 1.03, 2.50)] (Table S8). Tables S9 and S10 show the associations between the frequency of green space visits in winter and potential predictors of green space visits. The strongest predictor of the frequency of green space visits in winter was the perceived importance of a green environment, which is consistent with our results for green space visits in summer. We found some differences between the predictors of green space visits in summer and green space visits in winter. Perceived neighborhood greenness and the percentage of agricultural green space in a buffer of 3,000 m around the adolescent's home were significantly associated with green space visits in winter, whereas paternal level of education was not (Table S10). Adolescents who classified their neighborhood as "green" or "very green" visited green spaces more often for any type of activity in winter, whereas a higher percentage of agricultural green space in a buffer of 3,000 m was associated with a lower likelihood of visiting green space at least once a week for physical activities or any type of activity (Table S10). Sensitivity analyses without the predictor "perceived importance of a green environment" yielded results similar to those of the main analyses. However, perceived neighborhood greenness was significantly associated with green space visits for physical activity only when "perceived importance of a green environment" was omitted (Table S11). Adolescents who classified their neighborhood as "very green" visited green spaces more often for physical activities than adolescents who classified their neighborhood as "little to no green" [PR: 1.40 (95% CI: 1.00, 1.94)]. We also observed this positive trend of perceived neighborhood greenness for the other outcome variables, but these associations were nonsignificant.

Discussion

Main Findings

This study found that in Netherlands, 53% of adolescents aged 17 y visited a green space at least once a week in summer. Adolescents reported visiting green space mostly for physical activities and social activities and less often for relaxation and to

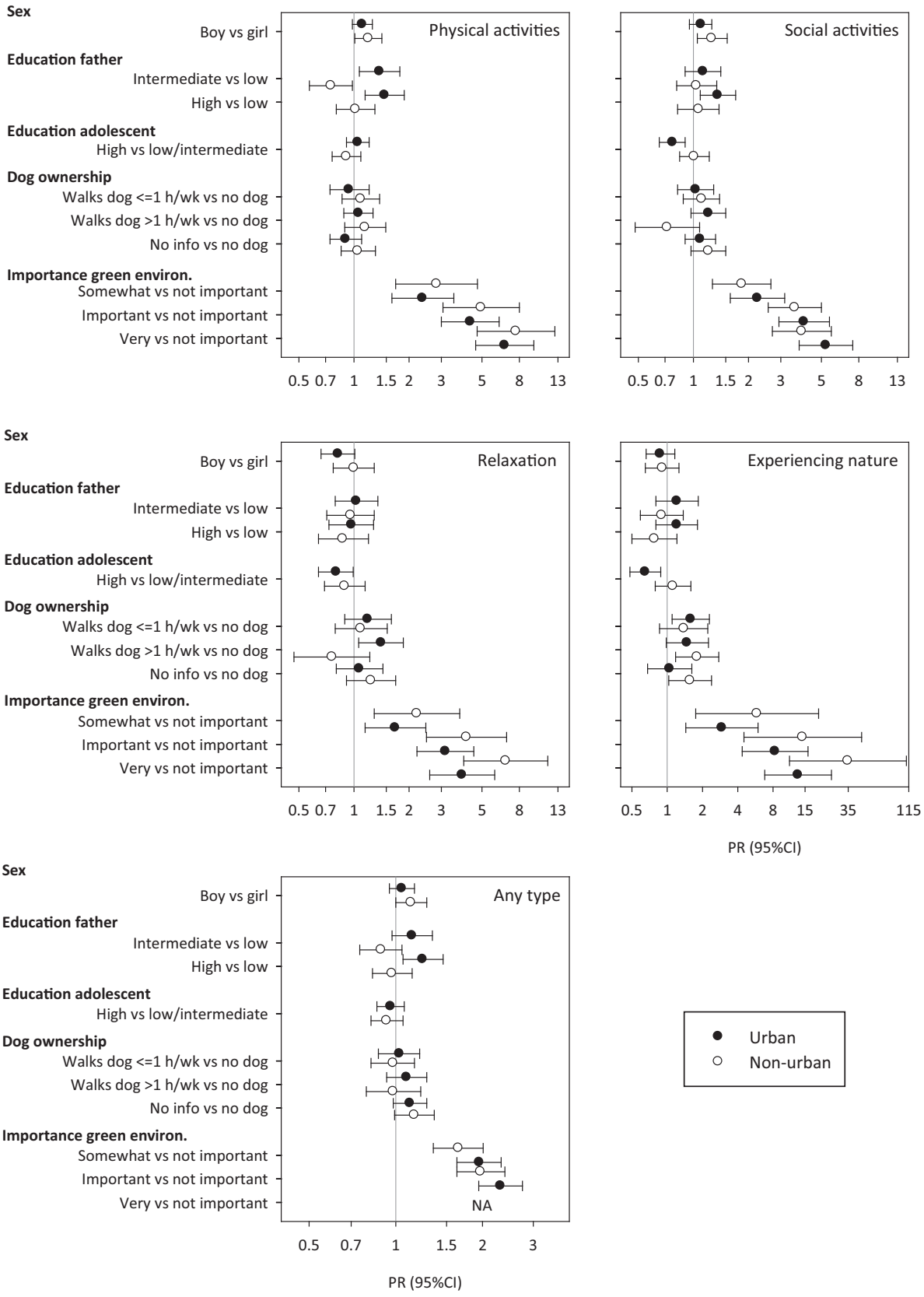

Figure 2. Predictors associated with visiting green space (yes/no) stratified by level of urbanization from multivariable log-binomial regression analysis. The prevalence ratios are adjusted for all variables presented in this figure. Note: The level of urbanization is divided into two categories: urban (≥1,000 addresses per km^2) and nonurban (<1,000 addresses per km^2).

experience nature and quietness. The strongest predictor of green space visits in adolescents was the perceived importance of a green environment. Boys and adolescents with highly educated fathers visited green spaces more often for physical and social activities. Adolescents who own a dog visited green spaces more often to experience nature and quietness. The frequency of green space visits was not significantly associated with the objectively measured quantity of residential green space.

Comparison with Other Studies

Previous studies in children and adolescents have focused on the frequency and predictors of park visits. To our knowledge, this is the first study that has examined the frequency and predictors of green space visits in general (not only park visits) in adolescents. Veitch et al. examined park visits of 8- to 16-y-old children living in disadvantaged areas of Victoria, Australia (Veitch et al. 2014). In this study, 75% of the children reported visiting parks. Among these children, 37% visited their "usual park" at least once a week and 69% at least several times per month (Veitch et al. 2014). Another study found in California that 78% of adolescents aged 12–17 y reported that they visited a park in the past 30 d (Babey et al. 2015). Flowers et al. examined 2,079 working-age adults in the United Kingdom and found that 68% of participants visited the green space closest to their home at least a few times a month (Flowers et al. 2016).

The present study showed that adolescents who own a dog visited green spaces more often to experience nature and quietness. Our results are in line with previous research that has shown that dog walkers are frequent users of green space (Lachowycz and Jones 2013).

We found that the perceived importance of a green environment was the strongest predictor of green space visits in adolescents. The frequency of green space visits was not associated with the objectively measured quantity of residential green space.

Our results are in line with a study by Flowers et al. that has shown that subjective predictors, such as nature relatedness (individual levels of connectedness with the natural world), are associated with the use of local green space in adults (Flowers et al. 2016). That study also found that the objectively measured percentage of local green spaces was not associated with the use of local green space (Flowers et al. 2016). Our findings are also consistent with a study that showed that the number of parks within a 1-mi radius around the adolescents' homes was not associated with adolescents' park use for physical activity (Ries et al. 2009).

In contrast, a study that examined 135 low- to middle-income children aged 8–14 y in southern California found that children used neighborhood parks more often when parks were closer to the children's homes (Dunton et al. 2014). The discrepancy between the current study and the study in southern California may be due to differences in study populations: Our study population was, on average, 17.8 y old and mainly consisted of middle- and highly educated families. Furthermore, park use was measured differently in the two studies. In the Californian study, park use of participants was measured by Global Positioning System (GPS) over a 7-d period, while the present study used questionnaires to assess the frequency of green space visits. Our results are also not consistent with two studies that examined green space visits in adults. Giles-Corti et al. showed that the likelihood of using public open spaces increased with increasing levels of access to public open spaces in 1,803 adults in Australia (Giles-Corti et al. 2005). Another study in the United States found that residents living closer to parks had a higher number of weekly park visits (Sturm and Cohen 2014).

Interpretation and Implications of Findings

We found that adolescents with fathers who are highly educated were more likely to visit green spaces at least once a week for physical and social activities and any type of activity. In contrast, highly educated adolescents were less likely to visit green spaces for social activities and relaxation than adolescents with a low/intermediate level of education. Maternal level of education was not associated with green space visits in adolescents. The educational level of the mother, father, and adolescent may be indicators of different constructs. Paternal level of education tends to be associated with family income and standard of living, whereas the educational level of the adolescent is more likely to be an indicator of the attitudes, preferences, and behaviors of his/her peer group. Maternal level of education may be an indicator of family lifestyle and health-related behaviors. This may explain the discrepancy between the associations of paternal level of education, maternal level of education, and the educational level of the adolescent.

The present study showed that the perceived importance of a green environment was the strongest predictor of green space visits in adolescents, suggesting that it is the adolescents' attitude towards a green environment that impacts green space visits. The frequency of green space visits was not associated with the objectively measured quantity of residential green space. For adolescents, other environmental attributes may influence the frequency of green space visits, like the quality of green space. No information on the quality of green space was available in the present study. Other explanations for the lack of an association between green space visits and the distance to the nearest park are the relatively short distances from the homes to parks and the frequent use of bicycles in our study population. Nearly 80% of the adolescents had a park within 1,000 m of their homes. In Netherlands, teenagers bike on average 2,000 km per year (Centraal Bureau voor de Statistiek 2015). In other words: parks were generally available and accessible (by bike) for our study population. It is therefore possible that the adolescents' attitudes towards green space (i.e., did the adolescents *want* to visit a green space?) influenced the frequency of green space visits more than the actual distance to residential green space.

The NDVI also includes street greenery and private green property (such as gardens), which are not included in our definition of green space visits. This may explain the absence of an association between the average NDVI in several buffers and the frequency of green space visits in our study. However, we also found no relation between the percentages of urban, agricultural, and natural green spaces with the frequency of green space visits. These percentages of green space are based on Top10NL, which does not include street greenery and private green space.

In the present study, adolescents reported how often they *intentionally* visit green spaces for specific purposes. We did not find an association between the objectively measured quantity of residential green space and visiting green spaces for physical activities. However, when the quantity of residential green space is higher, adolescents may use active modes of travel instead of passive modes of travel. The quantity of residential green space could therefore influence physical activity levels in adolescents.

Our finding that the quantity of residential green space was not associated with green space visits may indicate that self-selection bias, i.e., individuals choose to reside in neighborhoods that align with their preferences for green space visits, does not play a critical role in studies examining the health effects of green space in adolescents. Our findings may also have implications for the interpretation of studies examining the health effects of green space. Those studies mostly use objective measures to assess surrounding greenness, such as the NDVI, as a proxy for greenness

exposure. In those studies, there is no information on the actual green space visits by the study participants. Yet some proposed pathways through which green space may affect health require actual green space visits (Hartig et al. 2014). Our results suggest that the quantity of residential green space as measured by the NDVI or land-use maps may not be a suitable proxy for visiting green space in adolescents because the quantity of residential green space was not associated with the frequency of green space visits. It is therefore likely that pathways that do not require actual green space visits are involved in the associations between objectively measured green space and health in adolescents that have been reported in the literature.

There is a possibility of reverse causation in our study: It is unclear whether the perceived importance of a green environment actually causes a higher frequency of green space visits or whether a higher frequency of green space visits influences adolescents' attitudes towards a green environment. However, our finding that the perceived importance of a green environment was strongly associated with the frequency of green space visits may be relevant for public health policy. It indicates that not only the availability of residential green space, but also attitudes towards green space might be relevant targets for public health strategies. We were not able to examine the predictors of the perceived importance of a green environment, i.e., environmental attitudes. Future epidemiological studies are needed to explore the predictors of proenvironmental attitudes so that public health strategies to promote such attitudes could be implemented.

Strengths and Limitations

To our knowledge, this is the first study that has examined the perceived importance of a green environment as a predictor of green space visits in adolescents. Furthermore, we included several objective measures (the average NDVI; the percentage of urban, agricultural, and natural green space; and the distance to the nearest park) in several buffers to assess the quantity of residential green space in addition to perceived neighborhood greenness in the analyses.

However, this study has some limitations. The frequency of green space visits was self-reported and not objectively measured by, for example, GPS devices. We used the following question to assess the frequency of green space visits: "How often do you intentionally go to a green environment (not your own garden)?" No definition of a green environment was given to the study participants. It is possible that the adolescents interpreted this term in different ways. For example, some, but not all adolescents may have considered sports fields as green spaces. Since there is no universally accepted definition of green space, it is not possible to assess whether this has resulted in an over- or underestimation of the frequency of green space visits. The lack of a definition of a green environment may have resulted in differences in the reported frequencies of green space visits between adolescents that are no actual differences but caused by a different interpretation of the term "green environment."

Furthermore, information about the quality of green space was unavailable in the present study. Both perceived and objective quality of green space may be associated with the frequency of green space visits (Flowers et al. 2016; Lee and Maheswaran 2011; Ries et al. 2009).

Of the baseline PIAMA study population, 53% completed the questionnaire at the age of 17 y. There was selective loss to follow-up of children with lower paternal and maternal education (Wijga et al. 2014). This loss to follow-up may have influenced our observed frequencies of green space visits, since a higher level of paternal education was associated with more frequent green space visits in our study. However, we assume that the associations between potential predictors of green space visits and the frequency of green space visits would not be different in the general population of Dutch adolescents.

Our study population mainly consisted of adolescents who live in a house with a garden, which is similar to the general Dutch population (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties 2013). People who live in a house without a garden may visit green spaces more often. The results of our study may therefore not be generalizable to adolescents in other countries, where the percentage of homes with a garden is lower.

The present study examined the frequency and predictors of green space visits as reported among adolescents aged 17 y. Future studies are needed to assess these associations in other age groups as well.

Conclusion

This study found that more than half of the adolescents visited a green space at least once a week in summer, mostly for physical and social activities. The strongest predictor of green space visits among adolescents was the perceived importance of a green environment. The objectively measured quantity of residential green space was not associated with green space visits. Our results suggest that subjective variables are stronger predictors of green space visits than the objectively measured quantity of residential green space.

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